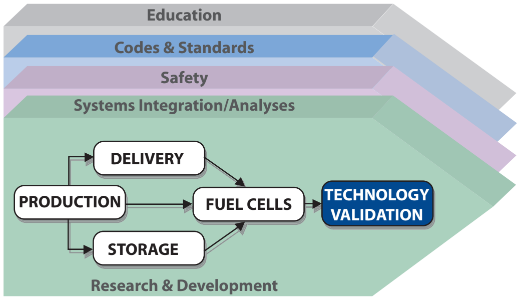
3.5 Technology Validation

The Technology Validation Program element is focusing on conducting learning demonstrations that emphasize co-development and integration of hydrogen infrastructure in parallel with hydrogen fuel cell-powered vehicles to enable an industry commercialization decision by 2015. Technology validation will test, demonstrate and validate total system solutions and use the results to refocus hydrogen R&D as appropriate.



3.5.1 Technical Goal and Objectives

Goal

Validate total system solutions for integrated hydrogen and fuel cell technologies for transportation, infrastructure and electric generation under real-world operating conditions for both the transition and mature market periods.

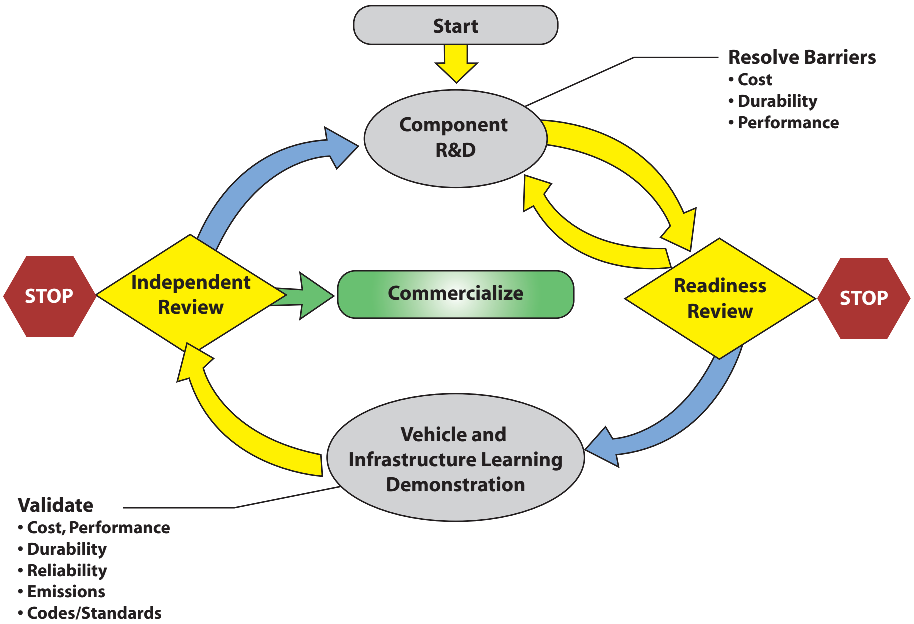
Objectives

- By 2008, validate an electrolyzer that is powered by a wind turbine at a capital cost of the electrolyzer of $600/kWe and 68% efficiency including compression to 5,000 psi when built in quantities of 1,000.
- By 2009, validate hydrogen vehicles that have greater than 250-mile range, 2,000-hour fuel cell durability and hydrogen infrastructure that results in a hydrogen production cost of less than $3.00/gge (untaxed), and safe and convenient refueling by trained drivers.
- By 2011, validate an integrated biomass/wind or geothermal electrolyzer-to-hydrogen system to produce hydrogen for $2.85/gge at the plant gate (untaxed).
- By 2015, validate hydrogen vehicles that have 300+ mile range and 5,000 hours fuel cell durability, and hydrogen infrastructure that results in a hydrogen production cost of $1.50/gge (untaxed), and safe and convenient refueling by trained drivers.

3.5.2 Technical Approach

The Technology Validation Program element will implement integrated, complex total systems (i.e., hydrogen production facilities and hydrogen vehicles) and collect data from them to determine whether the technical targets have been met under realistic conditions (see Figure 3.5.1). Technology validation learning demonstrations bring together teams of automotive and energy companies working together to address fuel cell vehicle and hydrogen infrastructure interface issues and to identify future research needs. The results of the validations will be used to provide feedback on progress and to efficiently manage the other Program element activities and to refocus research and development as needed.

Figure 3.5.1. The Role of Technology Validation



Although all the components of complex systems may have met their technical targets and goals, the resulting systems may fail due to unanticipated integration problems or real-world operating conditions that are outside the planned design parameters. Complete validation will require collecting sufficient data to develop statistical confidence that the systems meet customer expectations for reliability and durability, while satisfying regulatory requirements (e.g., emissions and safety). System and sub-system level models will be developed to analyze the performance data collected from the integrated hydrogen and fuel cell systems and validate the component technical targets. The complete system models will also be used to validate the technical approach being taken and redirect it as necessary.

To accomplish all of the objectives, a three-phase effort is envisioned with performance milestones that have to be met at the end of phases 2 and 3. (Figure 3.5.2). The current Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project is phase 2 to be followed by phase 3, which is the pre-commercialization project to be completed by 2015.

Figure 3.5.2. Transportation and Infrastructure Timeline

	Phase 1 Technical Feasibility (2000)	Phase 2 Controlled Fleet Test and Evaluation (2004)	Phase 3 Commercial Readiness Demonstrations (2009)	Commercialization Phase (2015)
Vehicles Objective	Test FC vehicle performance and feasibility	Evaluate use of FC vehicles under real-world conditions	Demonstrate commercial viability of FC Fleet Vehicles	Investment to establish manufacturing plants & sales/service
Infrastructure Objective	Demonstrate H_2 fueling station; Analyze fuel options Primarily trucked in liquid	Onsite generation from multiple feedstocks Renewable & fossil fuels	Demonstrate commercial viability of hydrogen infrastructure Most cost effective sources by region	Investment for substantial numbers of all stations to be H_2 capable
Go/No Go Decision Points			**Decision Criteria–Phase 2:** Validate hydrogen vehicles that have greater than a 250-mile range, 2,000-hour fuel cell durability and hydrogen infrastructure that results in a hydrogen production cost of less than \$3.00/gge (untaxed), and safe and convenient refueling by trained drivers.	**Commercialization Decision Criteria:** Validate hydrogen vehicles that have a 300+ mile range and 5,000 hours fuel cell durability, and hydrogen infrastructure that results in a hydrogen production cost of \$1.50/gge (untaxed)1, and safe and convenient refueling by trained drivers.

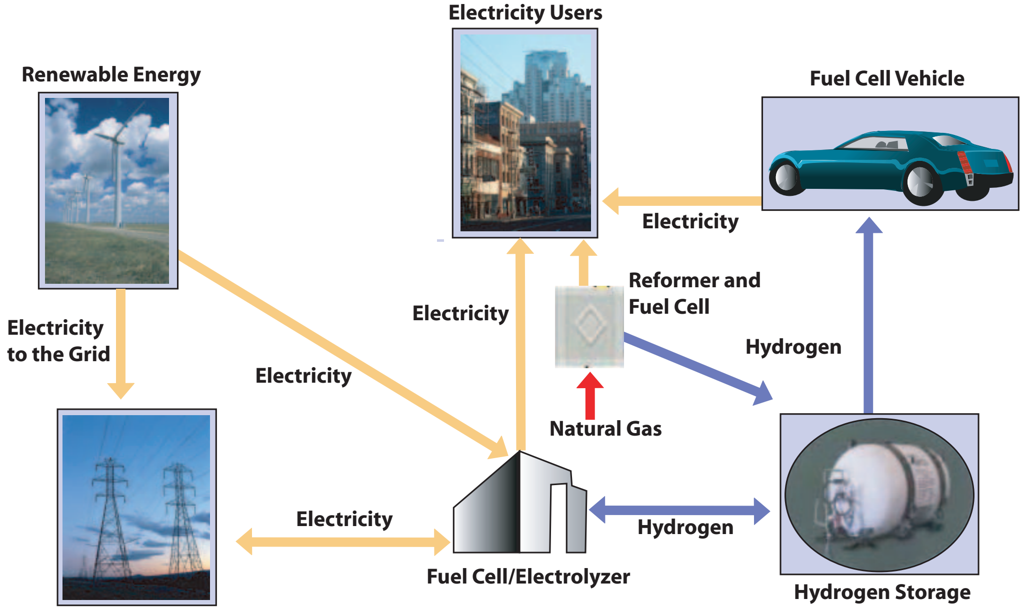
R&D continues concurrently to address key cost and performance barriers

Small-scale distributed hydrogen production from natural gas is the furthest along in development and is being field evaluated by constructing hydrogen refueling stations. Electrolyzer technology is available today, but using electricity produced from fossil fuels to make hydrogen creates large amounts of greenhouse gases. However, electrolyzers open the possibility of using electricity made from renewable and nuclear sources to produce carbon-free hydrogen. A demonstration of carbon-free hydrogen using an electrolyzer is planned to validate the technology and the potential of this approach.

The energy station concept includes steady production of hydrogen from natural gas for vehicles and use of a fuel cell or alternative power systems to produce electricity. When excess hydrogen is available, it is stored for use when electricity demand is high and to refuel vehicles. The advantages of producing both hydrogen and electricity in energy stations include the following: it provides access to lower cost natural gas because of the higher volume required; it facilitates staged implementation of refueling components to better match the demand from vehicles; and it allows use of a larger reformer or the fuel cell itself (internal reformation) that will lower the per-unit capital costs of hydrogen production.

Power parks can combine these near-term hydrogen production technologies into a single system that produces hydrogen and electricity. The power park concept is amenable to distributed production of hydrogen from natural gas, and opens the possibility of incorporating wind and solar energy effectively (see Figure 3.5.3). Analysis of the power park concept is ongoing and a future validation test is planned that will include the option of a vehicle fuel cell being a back-up electric generator.

Figure 3.5.3. Example of a Power Park Concept



Technical analyses will be initiated and used to assess current and guide future activities, including analyses of the following:

- Vehicle component and vehicle system performance maps
- Early infrastructure options
- Energy stations
- Power parks that include integrated renewable hydrogen production systems that combine electrolysis powered by wind, solar, hydropower, or geothermal with natural gas or biomass gasification systems

Analysis of a vehicle fuel cell power generator as a back-up power option for distributed power systems will be considered along with other power park options.

3.5.3 Programmatic Status

Table 3.5.1 summarizes current technology validation activities, which focus on hydrogen vehicles and infrastructure, energy stations, power parks, and renewable/hydrogen system demonstrations.

Current Activities

Table 3.5.1 Current Technology Validation Activities

Organization	Activities
Hydrogen Vehicles and Infrastructure	
DaimlerChrysler/ BP, Ford/BP, GM/Shell, Texaco Energy Systems/ Hyundai	The Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project will be a learning demonstration that will help DOE refocus its research and development efforts, provide insight into vehicle and infrastructure interface issues, assess the status of the industry and help address codes, standards and safety issues
California Fuel Cell Partnership (CaFCP)	The CaFCP is helping to encourage early introduction of fuel cell (FC) passenger cars and buses in California. The partnership is examining fuel infrastructure issues and beginning to prepare the California market for this new technology. SunLine Services Group, Inc. and the Alameda-Contra Costa Transit District (AC Transit), both associate members of the CaFCP, are acquiring fuel cell transit buses using compressed hydrogen.
General Motors and Selected Universities	Develop and test student-designed hybrid fuel cell and internal combustion engine vehicles.
Natural Gas to Hydrogen Refueling Stations	
SunLine Services Group, Inc. and Hydradix	Operating a hydrogen fuel cell vehicle (FCV) refueling station in Coachella Valley, California that uses hydrogen made from natural gas autothermal reformation and electrolysis of water using electricity generated from PV arrays.
Air Products and Chemicals Inc.	Build and operate a steam methane reformation refueling station at the Pennsylvania State University in State College, Pennsylvania, that can produce hydrogen for less than $3.00/gge (untaxed) when built in quantity. Novel compression and fueling apparatus to be incorporated and tested at Pennsylvania State University refueling station.
GTI	Demonstrate a natural gas-to-hydrogen refueling station that can produce hydrogen for less than $3.00/gge (untaxed) when built in quantity.
Stationary Hydrogen Fuel Cells for Co-Production of Hydrogen and Electricity (Energy Stations)	
Air Products and Chemicals Inc.	Build and operate energy station in Las Vegas, Nevada to validate $3.60/gge hydrogen cost and 8¢/kWh electricity cost (untaxed).
Air Products and Chemicals Inc.	Validating a high-temperature fuel cell as an energy station.

Renewable Hydrogen Production Systems and Power Parks	
Sandia National Laboratory and Air Products Corp.	Performing parametric studies of the components needed, the relative production of hydrogen and electricity, the resulting footprints of these systems, total system cost, and the anticipated cost of the hydrogen and electricity produced.
Hawaiian Electric Company, Detroit Edison and Arizona Public Services	Construction and operation of three Power Park systems in Hawaii, Michigan, and Arizona. Each will determine the relevant codes, safety standards, and engineering data required for power parks. The operation of these systems will provide data to better understand the performance, maintenance, operation, and economic viability of power parks.
Clark Atlanta University	Developed technology to generate hydrogen from biomass and agricultural residue. Will test 1 kg/hour shift reactor using vapors from peanut shell pyrolysis. This technology is applicable to all forms of biomass.
Praxair	LAX Hydrogen Fueling Station – Design and demonstration of a small footprint hydrogen production facility suitable for placement at existing refueling stations.

3.5.4 Technical Challenges

In addition to the technical barriers being addressed through RD&D in the other subprograms, there are obstacles to successful implementation of fuel cells and the corresponding hydrogen infrastructure that can only be addressed by integrating the components into total system solutions, such as FCVs and refueling infrastructure. To have confidence in these technologies, they must be evaluated in multiple systems to acquire sufficient data to validate statistical significance and be able to meet local, national, and international codes and standards. All integrated systems will have to meet safety regulations. A by-product of this approach to technology validation is that technical and system problems are revealed and component requirements can be better assessed.

The Learning Demonstration Project is an important first step towards bringing energy companies and automakers together to solve all elements of infrastructure and vehicle development that will support the President's Hydrogen Initiative in developing a path to a hydrogen economy. By 2009, when the project's targets of 2000 hours fuel cell durability operated in varied climates, 250 mile vehicle range and less than $3.00/gallon gasoline equivalent hydrogen fuel cost are validated, it will be an important measure that the industry commercialization decision by 2015 will be on schedule.

In addition, the demonstration of high temperature coproduction systems (energy stations) could potentially validate a complete system solution to meet a 2010 target for hydrogen fuel production cost of $1.50/gallon gasoline equivalent. The demonstration of power park concepts that utilize renewable and fossil fuel systems and automobile fuel cells as back-up or peaking power generation will allow utilities to increase overall efficiency in the electric generation system and allow automobile companies to increase the value of vehicle fuel cells.

3.5.4.1 Technical Targets

The Technology Validation Program element does not develop new component technologies, and therefore does not have technology targets. Instead, this Program element will validate individual component technical targets developed within the other subprograms when integrated into a complex system and review the future requirements for each component in such integrated systems. Specifically, once technical targets for each individual component have been verified under laboratory conditions, they will be validated under real-world conditions as part of learning demonstration and validation efforts.

3.5.4.2 Barriers

The following barriers will be addressed by the Technology Validation Program element to pave the way for commercialization of fuel cell and hydrogen infrastructure technologies.

A. Vehicles. In the public domain, statistical data for vehicles that are operated under both controlled and real-world conditions is very limited (i.e., data such as FCV system fuel efficiency and economy, thermal/water management integration, durability (stack degradation), and system durability). Most or all the information is proprietary. Vehicle drivability, operation, and survivability in extreme climates (particularly low temperature start-up and operation in hot/arid climates), are also barriers to commercialization. The interdependency of fuel cell subsystems is an important element that must be considered when developing individual subsystems. Development and testing of complete integrated fuel cell power systems is required to benchmark and validate targets for component development.

B. Storage. Innovative packaging concepts, durability, fast-fill, discharge performance, and structural integrity data of hydrogen storage systems that are garnered from user sites need to be provided for the community to proceed with technology commercialization. Current technology does not provide 300+ mile range without interfering with luggage or passenger compartment spaces, nor does it provide reasonable cost, efficiency and volume options for stationary applications. An understanding of composite tank operating cycle life and failure mechanisms and the introduction of potential impurities is lacking. Cycle life, storage density, fill-up times, regeneration cycle costs, energy efficiency, and availability of chemical and metal hydride storage systems need to be evaluated in real-world circumstances.

C. Hydrogen Refueling Infrastructure. The high cost of hydrogen production, low availability of the hydrogen production systems, and the challenge of providing safe systems including low-cost, durable sensors are early penetration barriers. Shorter refueling times need to be validated for all the storage concepts. Integrated facilities with footprints small enough to be deployed into established refueling infrastructures needs to be conceptualized and implemented. The overall hydrogen production efficiency and the quantity of greenhouse gas emissions in well-to-tank scenarios are not well understood in real world conditions. Interface technology to fast-fill tanks requires reliable demonstrations. Small factory-manufactured, skid-mounted refueling systems need to be proven reliable options in low-volume production systems, for sparsely populated areas with low anticipated vehicle traffic. Other concepts for energy stations, power parks, and mid-sized plants (i.e., 25,000 kg/day), including pipelines or mobile refuelers, need to be verified with respect to system performance, efficiency, and availability.

D. Maintenance and Training Facilities. Lack of facilities for maintaining hydrogen vehicles, personnel not trained in handling and maintenance of hydrogen and fuel cell system components, limited certified procedures for fuel cells and safety, and lack of training manuals are all barriers that must be overcome. Lack of real-world data in the public domain on refueling requirements and operations and maintenance (O&M), including time and material costs, of FCVs are additional barriers.

E. Codes and Standards. Lack of adopted or validated codes and standards that will permit the deployment of refueling stations in a cost-effective and timely manner must be addressed. A database also needs to be assembled that is relevant to the development of codes and standards to ensure that future energy systems based on these technologies can be efficiently installed and operated. Data on the impact of constituent hydrogen impurities on fuel cell and storage systems needs to be validated under real-world operating conditions.

F. **Centralized Hydrogen Production from Fossil Resources.** There are few data on the cost, efficiencies, and availabilities of integrated coal-to-hydrogen/power plants with sequestration options. Hydrogen delivery systems from such centralized production systems need to be validated and operated. Hydrogen separations at high temperature and high pressure and their integrated impact on the hydrogen delivery system need to be demonstrated and validated.

G. **Hydrogen from Nuclear Power.** Validate data on reaction rates, nonequilibrium reactions and material properties for the high-temperature production of hydrogen through thermochemical and electrochemical processes are limited. The cost and O&M of such an integrated system needs to be assessed before high-temperature nuclear reactors are designed and developed for hydrogen production. Hydrogen delivery options need to be determined and assessed as part of the system demonstration. Validation of integrated systems is required to optimize component development.

H. **Hydrogen from Renewable Resources.** There is little operational, cost, durability, and efficiency information for large integrated renewable electrolyzer systems that produce hydrogen. The integration of biomass and other renewable electrolyzer systems needs to be evaluated.

I. **Hydrogen and Electricity Coproduction.** Cost and durability of hydrogen fuel cell or alternative-power production systems and reformer systems for coproducing hydrogen and electricity need to be statistically validated at user sites. Permitting, codes and standards, and safety procedures need to be established for hydrogen fuel cells located in or around buildings and refueling facilities. These systems have no commercial availability, or operational and maintenance experience.

3.5.5 Technical Task Descriptions

The technical task descriptions for the Technology Validation Program element are presented in Table 3.5.2. Concerns regarding safety and environmental effects will be addressed within each task in coordination with the appropriate Program element. The barriers associated with each task (see section 3.5.4.2) are also included.

Table 3.5.2 Technical Task Descriptions

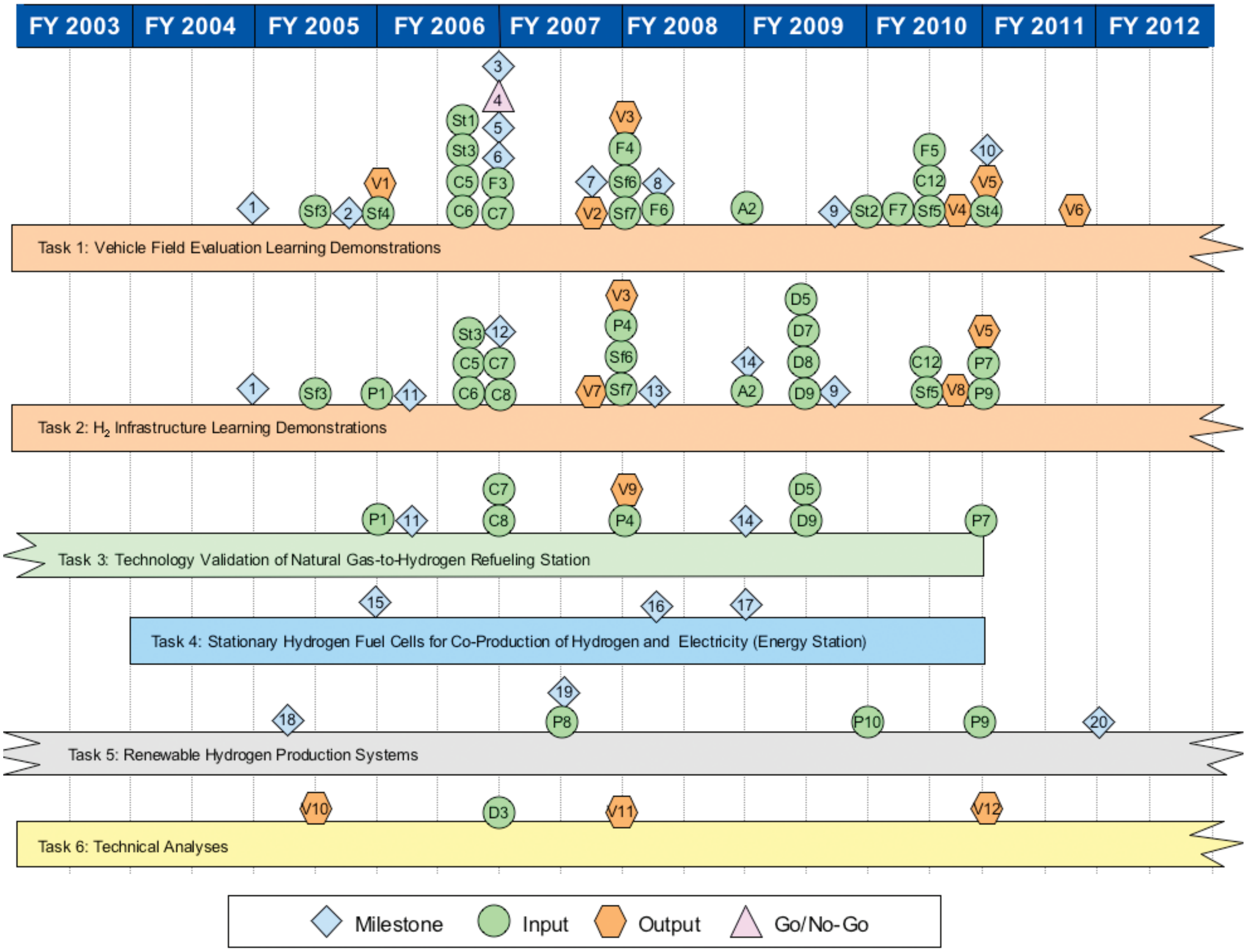
Task	Description	Barriers
1	**Vehicle Field Evaluation Learning Demonstrations** • Support acquisition of vehicles for controlled fleet demonstrations in strategic locations to collect data on FCV performance under real-world conditions. • Collect vehicle operating experience, including fuel economy, range, cost, drivability, cold-start, emissions, and durability. Data will be used for modeling, and composite results will be disseminated. • Identify maintenance, safety, and refueling requirements, including sensors and refueling connections. • Coordinate with and provide feedback to the FreedomCAR and Vehicle Technologies Program. • Support CaFCP demonstration by developing and providing technical guidance for the development of data acquisition plans covering fuel cell transit vehicles and light duty vehicles. • Support ChallengeX Student Demonstration Program for hydrogen hybrid vehicle that uses a small 10-kW fuel cell to augment an internal combustion engine.	A, B, C, D, E
2	**Hydrogen Infrastructure Learning Demonstrations** • Design, construct, and operate hydrogen refueling facilities to collect data on the integrated systems that include natural gas reforming and renewable hydrogen production systems to support fleet vehicles. • Document permitting requirements and experiences. • Develop a safety plan and then document its effectiveness, including malfunctions. • Validate efficient integrated systems and their ability to deliver low-cost hydrogen, which includes performance, O&M, purity (and specific impurities), and safety. • Collect and disseminate composite operating data to verify component performance using uniform protocols that include safety procedures, risk mitigation, and communication plans. • Collect and disseminate composite data from refueling sites in different geographic areas to verify performance and reliability under real-world operating conditions, including fast-fill and driver acceptance.	B, C, D, E, H, I
3	**Technology Validation of Natural Gas-to-Hydrogen Refueling Stations** • Build and operate natural gas-to-hydrogen refueling stations to collect data on reformer performance and reliability under real-world conditions. • Document permitting requirements and experiences. • Develop a safety plan and then document its effectiveness, including malfunctions that are encountered. • Validate the cost of hydrogen produced including all aspects of station O&M. • Collect and disseminate composite operating data to verify component performance using uniform protocols that include safety procedures. • Collect and disseminate composite data from refueling sites in different geographic areas to verify performance and reliability under real-world operating conditions including fast-fill and driver acceptance.	B, C, D, E

4	**Stationary Hydrogen Fuel Cells for Coproduction of Hydrogen and Electricity (Energy Station)** • Demonstrate stationary hydrogen fuel cells to collect data on fuel cell performance, reliability, and cost. • Collect statistical data on the durability of the hydrogen fuel cells. • Identify O&M and safety requirements for stationary hydrogen fuel cells. • Determine the economics of hydrogen and electricity coproduction compared to stand-alone hydrogen production facilities. • Collect and disseminate composite operating data to verify component performance using uniform protocols that include safety procedures. • Collect and disseminate composite data from refueling sites in different geographic areas to verify performance and reliability under real-world operating conditions including fast-fill and driver acceptance.	B, C, I
5	**Renewable Hydrogen Production Systems** • Validate integrated systems and their ability to deliver low-cost hydrogen, which includes system performance, O&M, durability, and reliability under real-world operating conditions. • Collect operating data to verify component performance using uniform protocols that include safety procedures. • Assess the economic viability of renewable hydrogen production, including system size and siting requirements based on resource location and transport economics.	E, H
6	**Technical Analyses** • Validate and improve models to refocus the R&D Program. • Analyze early infrastructure. • Analyze integrated renewable hydrogen production systems that combine electrolysis powered by wind, solar, hydropower, or geothermal with biomass gasification systems. • Analyze advanced energy stations and power parks for production of both hydrogen and electricity from renewable and natural gas sources. • Analyze a vehicle fuel cell power generator as a back-up power option for distributed power systems.	A, B, C, D, F, G, H, I

3.5.6 Milestones

Figure 3.5.4 shows the interrelationship of milestones, tasks, supporting inputs from subprograms, and outputs for the Technology Validation Program element. This information is also summarized in Table B.5 in Appendix B.

Figure 3.5.4. Technology Validation R&D Milestone Chart



For chart details see below and next page.

Milestones

1 Make awards to start fuel cell vehicle/infrastructure demonstration activity and for hydrogen co-production infrastructure facilities.
2 Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles.
3 Demonstrate (on a vehicle) compressed and cryogenic storage tanks achieving the 2005 energy and mass density targets.
4 Go/No-Go: Decision for purchase of additional vehicles based on projected vehicle performance and durability, and hydrogen cost criteria
5 Validate fuel cell demonstration vehicle range of ~ 200 miles and durability of ~ 1,000 hours.
6 Validate vehicle refueling time of 5 minutes or less.
7 Test results from student-designed hybrid fuel cell and internal combustion engine vehicles.
8 Validate (on a vehicle) 2.0 kWh/kg and 1.2 kWh/L compressed gas tank.
9 Validate FCVs with 250-mile range, 2,000-hour fuel cell durability, and a hydrogen cost of $3.00/gge (based on volume production).
10 Validate refueling time and durability for reversible complex hydride storage.
11 Validate cost of producing hydrogen in quantity of $3.00/gge untaxed.
12 Five stations and two maintenance facilities constructed with advanced sensor systems and operating procedures.
13 Total of eight stations and four maintenance facilities constructed with advanced sensor systems and operating procedures.
14 Validate $2.50/gge hydrogen cost.
15 Validate co-production system using 50 kW PEM fuel cell; hydrogen produced at $3.60/gge and electricity at 8 cents/kWhr.
16 Demonstrate prototype energy station for 6 months; projected durability >40,000 hours; electrical energy efficiency >40%; availability >0.80.
17 Validate prototype energy station for 12 months; projected durability >40,000 hours; electrical energy efficiency >40%; availability >0.85.
18 Demonstrate pyrolysis system for waste biomass.
19 Complete Power Park demonstrations and make recommendations for business case economics.
20 Validate $2.85/gge hydrogen cost from biomass/wind (untaxed and unpressurized) at the plant gate.

Outputs

V1 Output to Fuel Cells: Validate maximum fuel cell system efficiency.
V2 Output to Systems Analysis and Systems Integration: Final report for first generation vehicles, interim progress report for second generation vehicles, on performance, safety, and O&M.
V3 Output to Systems Analysis and Systems Integration: Technology Status Report and re-focused R&D recommendations.
V4 Output to Systems Analysis and Systems Integration: Final report for second generation vehicles on performance, safety, and O&M.
V5 Output to Systems Analysis and Systems Integration: Technology Status Report and re-focused R&D recommendations.
V6 Output to Fuel Cells: Validate Cold Start-Up capability (in a vehicle with an 8-hour soak) meeting 2005 requirements (specify cold-start energy)
V7 Output to Systems Analysis and Systems Integration: Final report on infrastructure and hydrogen quality for first generation vehicles.
V8 Output to Systems Analysis and Systems Integration: Final report on infrastructure, including impact of hydrogen quality for second generation vehicles.
V9 Output to Program: Submit final report on safety and O&M of three refueling stations.
V10 Output to Systems Analysis and Systems Integration: Hydrogen refueling station analysis - proposed interstate refueling station locations.
V11 Output to Systems Analysis and Systems Integration: Composite results of analyses & modeling from vehicle and infrastructure data collected under the Learning Demonstration Project.
V12 Output to Systems Analysis and Systems Integration: Final composite results of analyses & modeling from vehicle and infrastructure data collected under the Learning Demonstration Project.

Inputs

Sf3 Input from Safety: Safety requirements and protocols for refueling.
Sf4 Input from Safety: Safety requirements for on-board storage.
St1 Input from Storage: Compressed and cryogenic storage tanks achieving 1.5 kWh/kg and 1.2 kWh/L.
St3 Input from Storage: Complex hydride integrated system achieving 1.5 kWh/kg and 1.2 kWh/L.
C5 Input from Codes and Standards: Completed hydrogen fuel quality standard as ISO Technical Specification.
C6 Input from Codes and Standards: Technical assessment of standards requirements for metallic and composite bulk storage tanks.
F3 Input from Fuel Cells: Laboratory PEM technology with 2,000 hours durability.
C7 Input from Codes and Standards: Final standards (balloting) for fuel dispensing systems (NFPA).
F4 Input from Fuel Cells: Complete 4,000 hour testing of advanced MEA for stationary and transportation applications.
Sf6 Input from Safety: Sensor meeting technical targets.
Sf7 Input from Safety: Final peer reviewed Best Practices Handbook.
F6 Input from Fuel Cells: Verify cold start in 60 s of short stack.
A2 Input from Systems Analysis: Initial recommended hydrogen quality at each point in the system.
St2 Input from Storage: Advanced compressed/cryogenic tank technologies.
F7 Input from Fuel Cells: Technology with short-stack survivability at -40°C.
F5 Input from Fuel Cells: Laboratory PEM technology with 5,000 hours durability.
C12 Input from Codes and Standards: Final Hydrogen fuel quality standard as ISO Standard.
Sf5 Input from Safety: Safety requirements and protocols for refueling.
St4 Input from Storage: Full-cycle, integrated chemical hydride system meeting 2010 targets
P1 Input from Production: Verify hydrogen production technologies for distributed systems using natural gas with projected cost of $3.00/gge hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.
C8 Input from Codes and Standards: Draft standards (balloting) for refueling stations (NFPA).
P4 Input from Production: Verify hydrogen production technologies for distributed systems using natural gas or liquid fuels with projected cost of $2.50/gge hydrogen at the pump, untaxed, no carbon sequestration, assuming 100s of units of production per year.
D5 Input from Delivery: Compression technology recommended for validation.
D7 Input from Delivery: Recommendations liquefaction technology for potential validation.
D8 Input from Delivery: Recommended pipeline technology for validation.
D9 Input from Delivery: Off-board storage technology .
P7 Input from Production: Verify hydrogen production technologies for distributed systems using natural gas with projected cost of $1.50/gge hydrogen at the pump, untaxed, no carbon sequestration assuming 100s of units of production per year.
P9 Input from Production: Electrolysis system making hydrogen for $2.85/gge delivered.
P8 Input from Production: Down-select of high-temperature electrolysis technology based on research results.
P10 Input from Production: Hydrogen production system making hydrogen for $1.90/gge from biomass at the plant gate.
D3 Input from Delivery: Hydrogen delivery infrastructure analysis results.